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Editorial Comment

Real Time Ultrasound Quantification of Ventricular Function: Has the Eyeball Been Replaced or Will the Subjective Become Objective?*

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Assessing ventricular function with cardiac ultrasound. Cardiovascular ultrasound has demonstrated incredible growth and development over the past 25 years. The advent of two-dimensional echocardiography offered a real time noninvasive tomographic method of visualizing cardiac chamber size, global and regional ventricular function, valvular structure and great vessel and pericardial anatomy. Except for certain M-mode–derived variables, quantification of ventricular function from two-dimensional images has predominantly been subjective. The more recent cine loop technology and on-line digitizing systems, while allowing for comparison of echocardiographic images before and after interventions such as exercise stress, pharmacologic stress and operations, have not provided an easy method for objective quantification of ventricular function and hemodynamics.

Most physicians utilizing cardiovascular ultrasound to assess ventricular global and regional function have relied on the "educated eye." Certainly, the experienced echocardiographer is able to visually integrate and mentally reconstruct three-dimensional anatomic information. However, this subjective nature of "quantification" of ventricular function has been a major limitation of the ultrasound procedure, especially when applied to assessment of disease states or interventions that may alter global and regional function. Off-line analysis systems, while initially offering hope, were rapidly found to be time consuming, requiring manual tracing of still frame images for measurement and subject to problems of image degradation. Many leaders in the field of cardiovascular ultrasound and many investigators continue to seek methods of reliable on-line quantification of ventricular function (1–7).

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The present study. Because the use of cardiovascular ultrasound is expanding among cardiologists as well as cardiac anesthesiologists and cardiac surgeons, the need for reliable comparison of quantitative data on global and regional ventricular function after medical, interventional or surgical procedures has spurred continued research into the development of computer-assisted on-line border detection methods (1–7). The article by Perez and his associates (8) in this issue of the Journal may become a benchmark in the history of real time quantification of ventricular function by cardiac ultrasound.

Borders are going up in echocardiography: the converse of worldwide change. The system described by Perez et al. (8) is an extension of years of work on tissue characterization. For years the major emphasis in acoustic signal quantification has been the differentiation of diseased and healthy myocardial tissue (9–13). The system described by Perez et al. (8) and by Vandenberg et al. (14) utilizes a computer-assisted algorithm to analyze unprocessed acoustic signals from blood-tissue interfaces in real time along every scan line throughout every frame. This system creates a border interface between ventricular blood pools and myocardial tissue for any tomographic image plane. This method of determining borders differs from previous methods of brightness determination by providing acoustic tissue characterization or differentiation of blood-myocardial edges. The area of the blood pool is outlined and overlaps the real time two-dimensional image. Area changes within the myocardial blood pool can be visually scrutinized on a beat to beat basis. By drawing a region of interest, the computer can analyze changes in area, percent fractional area change and rates of change of area over time. Although area changes in any one given tomographic plane are not equivalent to volume changes and fractional area change is not equivalent to ejection fraction, these area changes do reflect alterations in ventricular volume and may be roughly correlated with ejection fraction and other volume-based variables.

The present study by Perez et al. (8), although based on a very small number of patients with a limited spectrum of cardiovascular disease, does present evidence that the automated border detection method allows acquisition of information similar to that which could be acquired by off-line analysis of two-dimensional real time images.

Limitations of current study. As with any new method, limitations have to be recognized, although they are not stumbling blocks to rapid future developments. That satisfactory results were obtained in only 72% of the subjects studied by Perez et al. (8) is of concern with respect to the widespread day to day application of this method among cardiologists, cardiac anesthesiologists and cardiac surgeons. The successful application of this technology will require a critical improvement of the automated border detection method to function in patients with technically difficult as well as technically superior echocardiographic images. A major limitation of this method is the gain sensi-

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tivity of the "backscatter" method. By increasing overall instrument gain and increasing noise to real signal levels, the automatic border representation of ventricular area shrinks until in essence there is no representation of a ventricular cavity. Because proper endocardial edge detection can be difficult in obese subjects and patients with chronic obstructive pulmonary disease, future developments will have to solve this gain sensitivity issue. Of major concern is that the best correlation was obtained from the parasternal long-axis views rather than the short-axis and apical views. The authors point out the difficulties encountered in tracking borders of the anterolateral, posterolateral and lateral walls from these views because of the perpendicular relation of these walls to the ultrasound beam. Because parasternal short-axis views, as well as apical four-chamber views, are critical for assessing regional left ventricular function in coronary artery disease, the ability of this technique to be widely applied in the spectrum of patients with regional and segmental dysfunction will have to be critically assessed.

Finally, the current study only compares echocardiographic on-line measurements with off-line measurements. Ideally the technique must be compared with other methods (nuclear magnetic resonance imaging, radionuclide studies and ultrafast cine computed tomography) of evaluating area changes, ventricular filling indexes and ventricular volume indexes.

The promise of the future. The ability to quantitate ventricular function in real time by the acoustic quantification method could allow for the assessment of pharmacologic, surgical and catheter-based interventions on global and regional left ventricular function. Hence, this technique could be of great use in critical care arenas such as intensive care units and operating rooms where transesophageal or epicardial echocardiography is being applied to the evaluation of left ventricular function. Potential future applications could include the following:

1. Automated regional wall thickening and motion analysis. It is conceivable that the acoustic quantification process could be extended not only to recognition of endocardial-blood pool interfaces, but also to the detection of endocardial-epicardial interfaces. If this could be provided visually and graphically in real time, the echocardiographic analysis of regional left ventricular function could be expanded, making this the procedure of choice for assessment of regional and potentially global left ventricular function. Obvious applications would be in the field of stress echocardiography (exercise or pharmacologic stress, for example) as well as to diagnostic and therapeutic interventional procedures in the catheterization laboratory. Similarly, this method could be used in the operating room to assist in the assessment of the regional function status after coronary artery bypass grafting or other interventions. Adding contrast echocardiographic procedures to this procedure might offer unique information not only on regional wall thickening but also on regional wall perfusion. Such data have obvious applications in the operating room and catheterization laboratory.

2. Hemodynamic monitoring. Currently, pulmonary capillary wedge pressure or direct left atrial pressure measurements are the clinical standards for measuring left ventricular preload in critical care areas and the operating room. Although pulmonary capillary wedge pressure is believed to be an accurate reflection of left ventricular end-diastolic pressure, wedge pressure remains at best an indirect measurement of ventricular preload. The most physiologically accurate measure of preload may be left ventricular end-diastolic volume. In critically ill patients, cardiovascular interventions are often determined by and adjusted to pulmonary capillary wedge pressure tracings. If the acoustic quantification of ventricular area is found to correlate well with ventricular volumes, this technique might offer a noninvasive monitoring system for real time left ventricular volume changes that would permit interventions to be based on data provided by this system. Also, if the integration of left ventricular pressure changes with area (and volume) changes could become a reality, a noninvasive pressure-volume relation could be established on-line and allow for instantaneous and serial quantification. The possibility of generating Starling curves on individual patients and tracking changes with intervention could potentially become a reality.

3. Variables of ventricular filling and emptying. The ability to differentiate area change over time and display such changes graphically in real time certainly could allow for measurements of ventricular filling and emptying indexes similar to those provided by other noninvasive technologies. Correlating this information with Doppler-derived indexes of diastolic function might allow for a more quantitative understanding of the complexities of systolic and diastolic function.

Questions to be answered. Certain clinical questions have to be answered and some technologic developments must occur for this technology to live up to its promise. Foremost among these are the following:

1. Can the gain-sensitive nature of the acoustic border quantification be standardized in any given patient and from any image plane?
2. Can a stable region of interest be maintained during intervention such as exercise or monitoring as occurs in imaging after cardiopulmonary bypass?
3. Is this method sensitive to very small changes in ventricular volume and does the area method correlate with ventricular volume?
4. Do changes in pulmonary capillary wedge pressure or left atrial pressure correlate with changes in ventricular area as detected by this method?
5. Can this method be used to generate a three-dimensional area and volume map of left ventricular and right ventricular function in both normal and diseased hearts?

Importance of current study. I believe that the current study ushers in a new era in the quantification of ventricular function. The ability to ascertain, in real time, moment to moment changes in area and the potential ability to give information on volume and pressure as well as on regional wall thickening could lead to the widespread application of this technology in both transthoracic and transesophageal echocardiographic studies. The authors (8) are to be complimented for validating an automated border detection method and, hence, offering hope that ventricular function can be quantified—an ability that has been lacking in the routine application of two-dimensional echocardiography.

References

1. Shah PM, Crawford M, DeMaria A, et al. Recommendations for quantitation of the left ventricle by two-dimensional echocardiography. J Am Soc Echocardiogr 1989;2:358–67.
2. Jenkins RE, Garrison JB. Automatic contouring for two dimensional echocardiography. Johns Hopkins APL Tech Digest: 1980:1139–43.
3. Garcia E, Gueret P, Bennett M, et al. Real time computerization of two-dimensional echocardiography. Am Heart J 1981;101:783–92.
4. Skorton DJ, McNary CA, Child JS, Newton FC, Shah PM. Digital image processing of two-dimensional echocardiography: identification of the endocardium. Am J Cardiol 1981;48:479–86.
5. Zhang LF, Geiser EA. An effective algorithm for extracting serial endocardial borders from two-dimensional echocardiograms. IEEE Trans Biomed Eng 1984;31:441–7.
6. Conetta DA, Geiser EA, Oliver LH, Miller AB, Conti CR. Reproducibility of left ventricular area and volume measurements using a computer endocardial edge-detection algorithm in normal subjects. Am J Cardiol 1985;56:947–52.
7. Geiser EA, Conetta DA, Limacher MC, Ostlund Stockton V, Oliver LH, Jones B. A second generation computer-based edge detection algorithm for short axis, two-dimensional echocardiographic images: accuracy and improvement in interobserver variability. J Am Soc Echocardiogr 1990;3:79–90.
8. Pérez JE, Waggoner AD, Barzilai B, Melton HE Jr, Miller JG, Sobel BE. On-line assessment of ventricular function by automatic boundary detection and ultrasonic backscatter imaging. J Am Coll Cardiol 1992;19:313–20.
9. Vered Z, Barzilai B, Mohr GA, et al. Quantitative ultrasonic tissue characterization with real-time integrated backscatter imaging in normal human subjects and patients with dilated cardiomyopathy. Circulation 1987;76:1067–73.
10. Milunski MR, Mohr GA, Pérez JE, et al. Ultrasonic tissue characterization with integrated backscatter: acute myocardial ischemia, reperfusion, and stunned myocardium in patients. Circulation 1989;80:491–503.
11. Masuyama T, Valantine HA, Gibbons R, Schnittger I, Popp RL. Serial measurements of integrated ultrasonic backscatter in human cardiac allografts for the recognition of acute rejection. Circulation 1990;81:829–39.
12. Vandenberg BF, Rath L, Shoup TA, Kerber RE, Collins SM, Skorton DJ. Cyclic variation of ultrasound backscatter in normal myocardium is view-dependent: clinical studies with a real-time backscatter imaging system. J Am Soc Echocardiogr 1989;2:308–14.
13. Vandenberg BF, Stuhlmuller BF, Rath L, et al. Diagnosis of recent myocardial infarction with quantitative backscatter imaging: preliminary studies. J Am Soc Echocardiogr 1991;4:10–8.
14. Vandenberg BF, Rath L, Stuhlmuller P, Melton HE Jr, Skorton DJ. Estimation of left ventricular cavity area with a new, on-line automated echocardiographic edge detection system. J Am Coll Cardiol 1991;17:291A.